Back to Table of Contents

Appendix AM-1

NFHCP Effectiveness Monitoring

Four broad Biological Goals and 15 Specific Habitat Objectives guided development of the NFHCP (see Table NFHCP1-1). These goals and objectives were designed to ensure that streams that are presently functioning properly are kept that way and streams that are not functioning properly improve through time.

In crafting the 53 commitments contained in the NFHCP, Plum Creek, the Services, and external scientists used the latest scientific information and models available. While significant knowledge about watershed processes and aquatic species conservation has been gained over the past 20 years, there is still much to learn. Effectiveness monitoring conducted under NFHCP Adaptive Management and Monitoring (see NFHCP Section 8) and other outside research will provide the data needed to verify that the Goals and Objectives of the NFHCP are being met and guide any necessary future modification of the NFHCP.

Effectiveness monitoring data will be used for a variety of purposes in adapting management under the NFHCP, including the following:

1. Determining when an adaptive management trigger is tripped
2. Determining when an adaptive management trigger should be changed
3. Informing decisions on biological relevance when a trigger is tripped
4. Establishing causal linkages between the observed environmental effect and situations imposed by NFHCP management actions or other external influences
5. Providing insight and information for developing management responses with the Services to address the issue.

I. How will Effectiveness Monitoring be Done?

Effectiveness monitoring involves testing specific hypotheses, and is very focused (tightly controlled in space). This is necessary in order to reliably establish cause/effect relationships between implementation of NFHCP commitments (management actions), changes in watershed/riparian processes, resultant shifts in stream channel morphology and fish habitat, and local habitat utilization by fish (see Plum Creek 1999a and Plum Creek 1999b for a more detailed discussion of the "cause/effect pathway").

Monitoring Fish Habitat

NFHCP effectiveness monitoring is focused on fish habitat rather than the fish themselves. It will closely investigate the linkages between implementation of NFHCP commitments (i.e., individual riparian prescriptions or road BMPs) and watershed processes (e.g., sediment delivery rates, LWD recruitment, stream temperature), and the effect of these watershed process changes on physical instream factors related to fish habitat (e.g., spawning gravel quality, pool frequency).

Biological data will also be collected, but it will be more restricted and will be used to determine the biological relevance, if any, of any plan-induced modification of physical habitat attributes. The majority of the biological monitoring will examine the effects of management actions upon habitat use by fish. That is, fish species diversity, age-class distribution, and population density will be measured in conjunction with measurements of physical habitat components, so as to determine if a plan-induced modification of habitat results in a net-reduction of habitat utilization by permit fish species. This information, combined with effectiveness monitoring data, is directly applicable in a determination of biological relevance if expected conditions (performance measures) are not being realized. Because collecting biological data can have a direct impact on fish, data collection will strictly follow federal permitting and guidelines for ESA listed fish.

Evaluation of the need to adapt management under the NFHCP will be initially "triggered" by changes in delivery rates of watershed processes and/or physical habitat trends (See Chapter 8). Biological data on fish habitat utilization from studies by Plum Creek or other researchers will be used in conjunction with other relevant information to verify that the tripped triggers indicate an appreciable impact to the effectiveness of the habitat to support permit species. If this "weight-of-the-evidence" approach shows that such an impact is occurring, then the relevant management prescriptions will be revised.

Applying Research Results to the Project Area

Due to the complexity of monitoring these causal linkages, effectiveness monitoring can only be undertaken on a subset of, or samples within, the Project Area. The sample locations must be carefully selected to ensure that the results can be broadly applied. The basis for extrapolating effectiveness monitoring results will vary by study, but could include stream gradient, stream width, riparian stand type, geologic type, soil type, geomorphic influences (e.g., glaciation), and climatic regime. Results from Plum Creek and external research may also be applied to specific Planning Area Basins that delineate the extent of a particular species distribution.

In contrast to effectiveness monitoring, implementation monitoring under the NFHCP is much more extensive (conducted throughout the Project Area). NFHCP implementation performance metrics are listed in Table NFHCP7-1 and are further described in Chapter 8. Extensive monitoring of NFHCP implementation, coupled with careful selection of effectiveness monitoring sites, will allow effectiveness monitoring results to be extrapolated with confidence.

CAMPs

Four specific effectiveness-monitoring projects are proposed for study under the NFHCP. These "Core Adaptive Management Projects" (CAMPs) were selected by Plum Creek and the Services as being most important in providing feedback on the effectiveness of the NFHCP. These projects are listed below and described later:

- Evaluating road BMP effectiveness regarding sediment delivery (CAMP1).
- Evaluating the effect of NFHCP riparian management on woody debris loads and fish habitat diversity (CAMP2).
- Evaluating the effectiveness of NFHCP riparian management commitments at minimizing stream temperature increases (CAMP3).
- Evaluating the effectiveness of Plum Creek's Grazing BMPs (CAMP4).

II. Where will Effectiveness Monitoring be Conducted?

Effectiveness monitoring will be undertaken throughout the NFHCP Project Area. Locations of specific sampling sites will be determined separately for each CAMP.

Focused Effectiveness Monitoring

For all, or some portions, of the data collected for the respective CAMPs, sampling will occur using a design stratified by the dominant geoclimatic regions that occur within the NFHCP Project Area. Since large scale geologic, geomorphic, and climatic patterns exert a strong influence upon physical and biological processes (i.e. erosion rates, vegetative growth patterns, hydrologic regime, etc.) that are deterministic of finer scale influences on channel structure, significant error in the development of cause-and-effect relationships can be reduced by a-priori stratification by these large scale processes.

Dominant geoclimatic regions within the Project Area were identified by evaluating the combinations of geologic district (sedimentary, metasedimentary, granitic, volcanic), geomorphic region (continental glacial, alpine glacial, fluvial, lacustrine), and amount of precipitation (wet =>20 inches/year, dry =<20 inches/year). Of all possible combinations, three geoclimatic regions were found to represent 83 percent of the Project Area:

- Wet-Metasedimentary-Alpine Glacial (14.4 percent)
- Wet-Metasedimentary-Continental Glacial (29.8 percent)
- Wet-Metasedimentary-Fluvial (38.8 percent).

Hence, these three regions were designated as the three dominant geoclimatic regions most representative of the Project Area. These regions were selected for stratification of CAMP study investigations so that any observed relationships within these watersheds would be representative of significant portions of the planning area. Hence, any needed management responses derived from the regionally stratified studies can be confidently extrapolated to that portion of the planning area that is geologically, geomorphically, and climatically similar (Plum Creek 1998c).

The types of studies to be undertaken in the dominant geoclimatic regions include measuring the amounts of fine sediment in spawning gravel (related to modeled and measured delivery from roads), and investigation of LWD recruitment and the effect on fish habitat and biological relevance. Evaluation of existing data suggests that a-priori stratification is justified since significant differences exist among import habitat features, even when controlling for factors such as channel gradient. For example, the average amounts of large woody debris per

100 meters, in undisturbed plane-bed/forced-pool-riffle channel types was found to equal 44.9 in the Wet-Metasedimetary-Alpine Glacial region, while found to equal 26.7 in the Wet-Metasedimentary-Fluvial region. Consequently, pool frequencies also differed. Findings of this type support the need for stratification of sampling, and subsequent extrapolation of results, within the dominant geoclimatic regions.

In addition to the CAMPs, other effectiveness monitoring efforts that involve Plum Creek and the Services (such as Washington Watershed Analysis and Washington Forests and Fish) will be focused on specific watersheds or regions. The information from these monitoring efforts will be available to inform cooperative management responses.

Dispersed Effectiveness Monitoring

While much of the effectiveness monitoring will be focused in dominant geoclimatic regions, some monitoring will necessarily be dispersed. This is a result of needing to sample conditions that may not be found within the regions (e.g., different geologic types, riparian types, channel types, fish species, etc.).

Examples of dispersed effectiveness monitoring includes reach-scale changes in stream temperature, effectiveness of grazing BMPs, Road Sediment Delivery Analyses, and long-term trends in riparian stands). Table AM-1-1 displays the array of monitoring measures and reporting metrics that will be addressed by the CAMP studies.

Results of dispersed monitoring may also suggest that NFHCP biological goals are not being met in a subset of the Project Area (e.g., within a given Planning Area Basin). While this may not be conclusive because of the relatively small sample size compared with Demonstration Watersheds, it will be used to adapt effectiveness monitoring through time. Another tool that will be used to identify particular situations where goals are not being met is the post-hoc evaluation of measured independent factors (covariates) that may exert a specific influence upon the dependent parameters being measured. For example, a covariate to be measured in CAMP 1 will be channel width. With repeated measures through time, monitoring may demonstrate that biological goals are being met in channels wider than a certain size, but not in channels narrower than a certain size. Hence, post-hoc covariate analysis can identify specific situations (e.g., channel size class) where NFHCP commitments should be modified.

TABLE AM-1-1
Effectiveness Monitoring, by CAMP, to be Initiated within the NFHCP Project Area, and the Information that will be reported at 5-Year Plan Reviews

	Effectiveness Monitoring	Information Reported at 5-Yr NFHCP Review
Road BMP Effectiveness (CAMP1)	• RSDA Model Validation (tubs study)—Base erosion rates and downslope sediment transport. • RSDA re-analyses through time. • Sediment delivery and effects on fish habitat.	• Net sediment reduction (%) since plan initiation. • Instream fine sediment trends.

TABLE AM-1-1
Effectiveness Monitoring, by CAMP, to be Initiated within the NFHCP Project Area, and the Information that will be reported at 5-Year Plan Reviews

	Effectiveness Monitoring	Information Reported at 5-Yr NFHCP Review
Riparian Effectiveness for LWD Recruitment (CAMP2)	• Trends in riparian stand conditions through time. • Validate assumptions in LWD model. • Validation of response of different channel types to LWD loads.	• Changes in relative density and average tree size for the largest 88 tpa in riparian stands. • Pool frequencies and characteristics. • Updated assumptions for LWD modeling parameters, revised model runs. • Net changes in canopy cover over project area.
Riparian Effectiveness for Temperature Control (CAMP3)	• Measure reach- and watershed-scale temperature effects and changes in habitat utilization by fish.	• Before/after harvest canopy closure changes. • Reach scale changes in temperature due to riparian harvest activity.
Grazing BMP Effectiveness (CAMP4)	• Measure trends in riparian conditions, stream channel characteristics, and habitat utilization by fish through time for a variety of grazing strategies.	• Analysis of differences in riparian condition trends between grazed and control reaches.

III. Core Adaptive Management Projects, Conceptual Designs

Four Core Adaptive Management Projects (CAMPs) are described in the remainder of this appendix. These are the description of the agreed conceptual designs for the final CAMPs that must be completed by the end of year 1 of the NFHCP as a mandatory collaborative management response. The conceptual designs are used at this stage because additional fieldwork is required before study designs can be finalized. An agreement on the conceptual design gives the Services the confidence that the studies will be of the appropriate rigor and gives Plum Creek the confidence that the magnitude and estimated cost of the studies will not appreciably escalate. Therefore, the final study design agreement must be based upon the conceptual designs that follow.

1. Core Adaptive Management Project #1: Evaluation of Road BMP Effectiveness

Introduction. A Biological Goal of Plum Creek’s Native Fish Habitat Conservation Plan (NFHCP) is to “Protect instream sediment levels where they are suitable for fish and contribute to restoration of instream sediment levels where they have been impacted from past Project Area management.” To help meet this goal, the NFHCP further defines four Specific Habitat Objectives (SHO):

1. Minimize sediment delivery to streams resulting from the construction of new roads and timber harvesting (SHO #4);

2. Reduce sediment delivery to streams from existing roads (SHO #5) ;

3. Create a net reduction in sediment delivery to streams (SHO #6); and

4. Contribute to restoration of the function of riparian vegetative communities for sediment filtration and streambank stability (SHO #7).

Numerous NFHCP road, grazing, and legacy restoration commitments were crafted to achieve these four Specific Habitat Objectives. These include commitments R1, R2, R5, R6, R7, G2, Lg2, and others. It is anticipated that watersheds presently having the highest sediment delivery will realize the most benefits from the NFHCP and watersheds with the least sediment delivery will have fewer benefits.

As part of the NFHCP, a trigger (Trigger "C") was developed to measure the success of attaining Specific Habitat Objective #6. If this trigger is "tripped," the "Adaptive Management Pathway" is initiated to evaluate if NFHCP conservation commitments should be changed. Trigger "C" is as follows:

> *The trigger will be observed if the pro-rated sediment reduction calculated across the Project Area is 30 percent or less, which is significantly less (at approximately 1 standard deviation) than the average weighted reduction of 49 percent calculated in the effects analysis. All watershed RSDA's will be averaged (i.e., weighted by watershed road length evaluated) to calculate net sediment reduction.*
>
> *Interim sediment reductions trigger values are as follows:*
>
> - *5-Year Review: At least a 10 percent reduction*
> - *10-Year Review: At least a 20 percent reduction*
> - *15-Year Review: At least a 30 percent reduction*

The purpose of CAMP1 is to investigate project-, watershed-, and landscape-scale changes in sediment delivery to streams associated with upland management. Information obtained from CAMP1 will provide a variety of information for the NFHCP adaptive management feedback loop, including: Results from CAMP1 studies will be used to guide adaptation of the plan over time. Specifically, this project will provide the following information for the NFHCP:

1. Provide monitoring data to determine if expected net sediment reductions are being attained. This information will be used to determine if Trigger "C" should be tripped at the 5-, 10-, and 15-year project reviews.

2. Inform the need to change the trigger over time. At the outset of the plan, Trigger "C" is based on a significant departure than what was modeled in the NFHCP effects analysis. Further investigation as part of this CAMP (or other external research) may reveal that this target is inappropriate. Trigger "C" could be modified based on this information.

3. Provide data that could be used in crafting Mandatory Collaborative or Cooperative Management Responses under adaptive management.

4. Provide information on the biological relevance of failing to meet sediment delivery reduction targets should Trigger "C" be tripped and the Adaptive Management Pathway invoked.

5. Aid in documenting and reasons why sediment delivery reduction targets were not met should Trigger "C" be tripped and the Adaptive Management Pathway invoked. This information could be used to specifically tailor Plan adaptation.

Results from this study are expected to have benefits beyond native fish conservation under the ESA. They can also be used on other forums, such as development of Total Maximum Daily Loads (TMDLs) under the Clean Water Act, and Source Water Protection under the Safe Drinking Water Act

Hypotheses. CAMP1 will try to answer five questions, three of which are presently framed as hypothesis tests. These questions are as follows:

Question 1: *Do base erosion rates on roads in the Rocky Mountain portion of the NFHCP Project Area significantly differ from base erosion rates predicted by the Washington watershed analysis methodology (WFPB 1997)?*

H_o = Measured base erosion rates do not significantly differ from base erosion rates predicted in the Washington watershed analysis methodology.

H_1 = Measured base erosion rates are significantly different than base erosion rates predicted in the Washington watershed analysis methodology.

Question 2: *Are driveable drain dips an effective strategy for reducing sediment delivery to streams?*

H_o = The presence of driveable drainage dips above stream crossings does not significantly affect sediment delivery rates.

H_1 = Driveable drainage dips significantly affect sediment delivery rates to streams.

Question 3: *Are inter-gravel fine sediment levels in streams maintained or improved as a result of implementing NFHCP conservation commitments?*

H_o = Trends in inter-gravel fine sediment levels does not significantly differ between NFHCP-treated watersheds and minimally impacted control watersheds.

H_1 = Where inter-gravel fine sediment levels in streams are significantly higher than minimally impacted control watersheds, fine sediment levels will decrease over time.

H_2 = Where inter-gravel fine sediment levels in streams are not significantly different than minimally impacted control watersheds, instream fine sediment levels will be maintained over time.

Question 4: *Are driveable drain dips and other drainage features (e.g., waterbars, ditch relief pipes), being placed in locations that prevent indirect sediment delivery to streams?*

At present, a specific hypothesis test has not been framed to answer this question. The purpose of this study is to improve our understanding of downslope sediment travel distances below road drainage features. Knowledge gained in this study will improve interpretations made during RSDA's and lead to continuous improvement of placement and design of drainage features.

Question 5: *Does net sediment reduction due to NFHCP implementation meet expected levels?*

This question does not lend itself to a hypothesis test. Road Sediment Delivery Analyses used in the original effects analysis will be re-visited over time to determine if expected net sediment reduction is being realized and if Trigger "C" should be tripped.

Experimental Design (Research Questions 1 & 2). This experiment will be set up to examine the effects of basic soil type and traffic intensity on sediment production (base erosion rates). Two different soil types will be analyzed: Soils derived from glacial till and soils derived from unglaciated metasedimentary bedrock. In excess of 90 percent of roads in the NFHCP Project Area occur in these two basic soil types. Additionally, two traffic levels will be studied: Roads that are receiving active log truck traffic (Active secondary roads) and roads that are presently inactive (administrative use only). Most other significant factors affecting erosion rates will be controlled for. These include:

- **Road Gradient—**Average road grades in each geologic type will be selected for study. We will be able to scale erosion rates to other road gradients based on published literature (e.g., Luce and Black 1999).
- **Cutslope and Tread Width—**Average cutslope and road widths will be selected for study.
- **Road Surface Treatment—**Only native surface roads will be studied since they comprise over 90 percent of all Project Area roads. Other research (Swift 1984; Kochenderfer and Helvey 1987) is available to estimate the benefits of road tread surface treatments.
- **Hillslope Gradient—**Sites will be located on average sideslopes based on GIS analysis
- **Time Since Construction—**This study will on examine erosion rates on roads greater than 5 years old.
- **Exposure—**Road segments will be located in areas without overhead canopy cover.

Other factors: slope position, aspect, and local weather will be examined as covariates in the statistical analyses, but will not be controlled for.

For each combination of soil type and traffic, five pairs of segments will be measured. This will yield a total of 20 plot pairs. Each segment will consist of an adjacent pair of 100m plots, with one of the 100m plots having a driveable drainage dip located 30m up-grade of the lower boundary of the plot (see Figure 1). Sample sites will be randomly selected given the criteria listed above.

Road runoff from plots will be routed into sediment settling tanks. Tanks will have an approximate capacity of 1.5m^3 and be made of steel or plastic. Ice (1986) measured trap efficiencies of 95 percent for particles greater than 0.02 mm for a 0.45 m^3 tank. Luce and Black (1999) found trap efficiencies exceeded 90 percent for 1.5 m^3 tanks similar to those proposed in this study.

Tanks will be annually weighed and emptied in late September (or more frequently as needed). Using Equation 1, the mass of sediment in each tank can be calculated. At each site, precipitation levels will be measured during the snow free period using rain gauges. Traffic levels will be measured with counters.

The primary statistical analyses will be one-sample t-tests that compare the mean annual sediment yield measured in this study with the predicted erosion rates for the Washington watershed analysis methodology (Table 1). Additional two-sample t-tests will be compared to determine if sediment yield from road segments with drain dips differs from road segments without dips.

This study will be initiated as a pilot in the summer of 2000. This will involve setting up two sites (one "pair" in each soil type). The remaining 18 sites would be set up in the summer of 2001. This study is planned to continue for three full years (completed in fall of 2004).

Experimental Design (Research Question #3). The intent of this study is to determine if:

- There are detectable differences in instream fine sediment levels when comparing roaded watersheds to similar watersheds exhibiting minimal anthropogenic disturbance

- Reductions in road sediment delivery to streams (through NFHCP implementation) will result in subsequent reductions of instream fine sediment levels, so that levels in roaded watersheds tend to approach, and ultimately become similar to, levels in comparable minimally disturbed watersheds

This study involves a limited, but intensive, analysis of fine sediment levels in watersheds that are representative of the three dominant geoclimatic regions in the Project Area. In each dominant geoclimatic region, two watersheds will be identified, one experimental and one control. Watershed selection will primarily be based on two factors: 1) watersheds should be as similar as possible in drainage area, percentage representation of landforms and soil types, and precipitation regime, and 2) one watershed (the control) must exhibit minimal anthropomorphic disturbance (i.e., forestry, road density, agriculture, residential development) while the other watershed (the experimental) must exhibit relatively extensive management history with significant opportunity for road drainage improvement, as well as opportunity for ongoing timber harvest activities. Within each watershed, a stream reach exhibiting a high sensitivity to fine sediment will be selected. These stream reaches should be near the watershed outlet so as to reflect the integrated sediment regime of the entire catchment area. Within each stream reach, three representative pool/riffle interfaces will be selected and four sediment samples will be collected at each tailcrest, equally spaced across the wetted width of the channel. McNeil core samplers will be used to collect all 12 samples within each reach. McNeil core data will be taken annually for the first 5 years of the plan and biennially thereafter.

In conjunction with instream fine sediment monitoring, a sediment delivery budget will be completed. This budget will estimate: 1) road sediment delivery (per WFPB 1997); 2) in-channel storage (volume) of fine sediment; 3) bank erosion rates; 4) landsliding (visible on photographs); 5) surface erosion from hillslopes; and 6) near-channel landslides not visible on aerial photos. This watershed sediment budget will be updated through time and be related to trends in instream fine sediment levels. This budget will have to be periodically updated.

Trends in fine sediment levels will be directly compared with estimates of sediment delivery over time. Core samples will be analyzed and compared among the two watersheds within each dominant geoclimatic region so as to ascertain if reductions in road sediment delivery result in a subsequent reduction of instream fine sediment. The fine sediment trends among the representative watershed can then be compared to determine if there is an effect of geoclimatic region upon BMP effectiveness in reducing instream fine sediment.

Timeframe. This study would be initiated by Year 2 of the NFHCP.

Experimental Design (Question #4). Several studies have examined sediment travel distances below roads (Burroughs and King 1985; Megahan and Ketcheson 1996; Brake et al. 1999; Packer 1967). However, these studies have a variety of limitations that limit their applicability to evaluating NFHCP Project Area management. Burroughs and King (1989) examined sediment travel distances in the Horse Creek experimental watershed (metasedimentary geology) in north central Idaho. Their study examined travel distances below fills and ditch relief culvert outfalls. Because most Project Area drainage features are driveable drainage dips, this study has limited benefit. Megahan and Ketcheson (1996) examined sediment travel distances below a variety of drainage feature types, however it was conducted in a geologic type (granitics) that comprises less than 3 percent of the NFHCP Project Area. Brake et al. (1999) studied travel distances below ditch relief pipes in the Oregon Coast Range.

One study that was conducted in parts of the Project Area was Packer (1967) reporting on data collected in the late 1950’s. Unfortunately summary results of travel distances were not presented and the original data are not available. Additionally, this study examined road management practices that are not in use today.

This study proposes to measure observed sediment travel distances below drainage feature outfalls in the dominant geoclimatic regions in the NFHCP Project Area and relate travel distance to a variety of physical factors. Factors that might be explored include:

- Time since construction
- Soil type
- Hillslope gradient

- Hillslope obstructions/vegetation
- Presence of filter windrows
- Drainage feature type
- Road length draining to drainage feature
- Road gradient
- Presence of road treat surfacing

While this study will utilize ocular estimates of travel distance, it will be validated with hillslope sediment traps. Results of this study can be readily incorporated to Project Area management, particularly aiding foresters in determining the physical location and spacing of drainage features. Results can also be used to improve estimates of indirect delivery made during Road Sediment Delivery Analyses.

Timeframe. This study will take 2 years to complete and would be initiated in Year 3 of the NFHCP with the goal of being completed by the 5-year review.

Experimental Design (Question #5). This study will provide the information to determine if Trigger "C" is tripped at the 5-, 10-, and 15-year reviews. It will estimate the cumulative net benefits of upgrading old roads (R5), treating Hot Spots (R6), abandoning surplus roads (R7), and constructing new roads to enhanced standards (R2).

The first step will involve an examination of the 17 watershed Road Sediment Delivery Analyses (RSDA's) used in the original NFHCP/DEIS effects analysis. In each of these watersheds, the specific road segments for which Plum Creek has direct or shared management responsibility that will be governed by the NFHCP will be identified. Based on the original RSDA's, sediment delivery from these road segments will be summarized and constitute the pre-NFHCP baseline. It is this baseline that future reductions will be compared against.

This projected amount of sediment delivery reduction will be compared with the levels of road upgrading that has occurred in the individual watersheds. Because we know the BMP condition of all roads throughout the Project Area (Per NFHCP Commitment R3 and R4), we will be able to estimate levels of sediment reduction across the Project Area, individual Planning Area Basins, and specific geoclimatic regions. This information could be used to inform the need for a customization of Trigger "C" or some other Cooperative Management Response.

Timeframe. Prior to the 5-, 10-, and 15-year reviews, the NFHCP-governed road segments identified above will be field-measured and re-modeled. Any roads constructed since the start of the NFHCP will also be included in the RSDA. Any roads abandoned since the NFHCP was initiated will also be included. Sediment delivery based on the reanalysis will then be compared against the original delivery estimates to determine if Trigger "C" is tripped.

Literature Cited for CAMP 1

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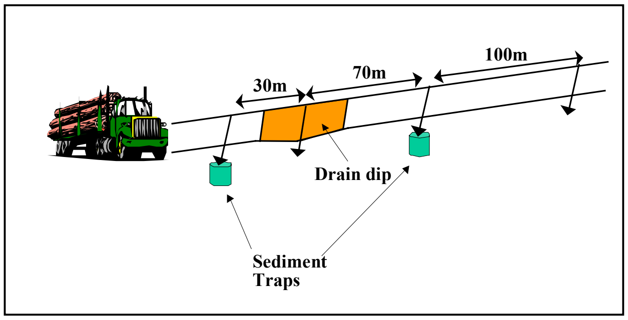
Washington Forest Practices Board (WFPB). 1997. Standard methodology for conducting watershed analysis. Version 4.0.

Figure 1. Design of sediment measuring sites. Each measured road segment will consist of a pair of plots. Both plots will be 100m in length, but one will include a dip located 30m above the lower boundary of the plot



Equation 1. Formula for calculating the mass of sediment in settling tanks

$$M_s = {(M_{tsw} - M_{tw})\rho_s}\Big/{(\rho_s - \rho_w)}$$

Where:

M_s = Mass of sediment

M_{tsw} = Mass of tank, sediment, and water

M_{tw} = Mass of tank and water

ρ_s = Density of sediment (~ 2650 kg/m^3)

ρ_w = Density of water (1000 kg/m^3)

Table 1. Base erosion rates as predicted by the Washington Watershed Analysis Methodology. Glacial till soils are assumed to have a "moderate" erodibility and metamorphic soils are assumed to have a "low" inherent erodibility. Numbers shown are for mean annual precipitation rates less than 47 inches per year.

	Glacial Till (Moderate)	Metamorphic (Low)
Light Traffic (Inactive) -	30 tons/acre/year	10 tons/acre/year
Moderate Traffic(Active Secondary) -	60 tons/acre/year	20 tons/acre/year

2. Core Adaptive Management Project #2: Effect of Riparian Management on Woody Debris Loads and Fish Habitat Diversity

Introduction. One biological goal of Plum Creek's Native Fish Habitat Conservation Plan (NFHCP) is to:

> *"Protect instream habitat diversity where it is suitable for native fish and contribute to restoration of instream habitat diversity where it has been impacted by past Project Area management."*

To help meet this goal, the NFHCP further defined five Specific Habitat Objectives (SHO), two of which will be evaluated against adaptive management triggers calculated under this CAMP:

1. Minimize impacts to large woody debris (LWD) recruitment and bank stability in harvested streamside stands (SHO #8);

2. Minimize impacts to overhanging stream banks because of grazing or riparian timber harvest (SHO #9);

3. Improve the ability of riparian forests to provide a broad scope of riparian function to streams (SHO #10);

4. Improve the function of riparian vegetative communities for overhanging banks and other habitat diversity through passive and active restoration (SHO #11);

5. Create a net increase in LWD recruitment potential and other riparian functions in the Project Area (SHO #12)

Riparian management commitments Rp1 – Rp9 were developed to help achieve these objectives. As part of the NFHCP, two "triggers" were developed to measure the success of attaining SHO #8 and SHO #12. Also, data collected under CAMP 2 will be used to calculate a trigger that measures the success in attaining SHO #3. This latter objective addresses the Cold biological goal, but the trigger evaluation is included in this CAMP because a common study is being used to calculate it and the trigger for SHO #12. If these triggers are "tripped," then the "Adaptive Management Pathway" is initiated to evaluate if NFHCP conservation commitments should be changed. The triggers are described below.

The purpose of Core Adaptive Management Project #2 (CAMP2) is to provide timely information on the effectiveness of riparian management commitments. Because the effects of timber harvest on fish habitat conditions may not be evident for decades, these studies are intended to provide early indications of any need to change commitments. The results of CAMP2 studies will be used to:

1. Validate the assumptions used to forecast LWD loads. This information will be used to determine if Trigger D should be tripped at the 5- and 10-year project reviews.

2. Provide data to determine if LWD recruitment potential over the Project Area is improving through time. This information will be used to determine if Trigger E should be tripped at the 15-year and subsequent project reviews.

3. Provide data to determine whether there is a net increase in canopy cover in riparian stands over time. This information will be used to determine whether Trigger B should be tripped at the 10-year and subsequent reviews.

4. Provide information that would be useful in modifying or refining any of the three triggers under this CAMP.

5. Provide information that would contribute to a biological relevance determination should triggers B, D, or E be tripped.

6. Provide information that may diagnose the reason for failing to meet specific habitat objectives. This kind of information would be used in the development of a Mandatory Collaborative Response should it be required.

7. Provide data that can be used in crafting a Cooperative Management Response in order to improve the ability of the NFHCP to meet specific habitat objectives.

Triggers Calculated Under Camp 2

Trigger D. Trigger D was developed as an "early warning indicator" (Cairns et al. 1993) for monitoring the success of SHO #8, which specifies that the NFHCP will minimize impacts to large woody debris recruitment related to streamside harvest. Ideally effectiveness monitoring involves the physical measurement of the habitat parameters used in the objective. However, under trigger D, modeled LWD loads are used as a basis instead of measured LWD loads, because changes in actual LWD loads are not expected to be evident for two or more decades after riparian timber harvest. This response time is too slow to provide meaningful feedback on the effectiveness of NFHCP riparian prescriptions in a time frame that is useful for adapting management. LWD modeling was used during development of NFHCP riparian commitments as a tool to assess the ecological tradeoffs of different harvest treatments (Plum Creek 1999a). Assumptions used in the modeling were deliberately conservative to avoid inflating LWD forecasts. Several CAMP2 studies are designed to validate these assumptions. Using validated or corrected assumptions, the LWD model will be run again at the 5-year review and at the 10-year review. If the new model runs (using the original model with validated assumptions) show that the initial LWD projections underestimated the impact of streamside logging by 20 percent or more, then trigger D will be tripped.

Trigger E. Trigger E was developed to evaluate the success of the NFHCP in meeting SHO #12, which is to achieve a net increase in woody debris recruitment potential. This requires observations of riparian stands that have not been harvested as well as those that have. In riparian areas with opportunity for timber harvest, modeling allowed the assessment of tree removal on LWD recruitment. Riparian harvest prescriptions were developed to minimize these impacts. Riparian conditions in the remainder of the project area that had been harvested prior to the NFHCP (~66 percent) were not modeled but are expected to improve as those stands develop and recover from past harvests. Measuring the potential for riparian stands to recruit woody debris to streams is a difficult task within timeframes that are meaningful to NFHCP adaptive management. Growth of young streamside trees can be measured through time, but increased in-channel LWD derived from these trees may not be measurable for many decades. Therefore, observations will be made of two aspects of riparian stands as a surrogate for woody debris recruitment potential: Will stands become denser? Will trees in the stands become bigger? The evaluation of the NFHCP assumes that the answer to both of these questions is yes. CAMP 2 will measure the relative density and the average size of the largest 88 trees per acre of riparian stands. If these metrics decrease or stay the same, trigger E will be tripped. Because measurable improvements are expected to be modest, trigger evaluation prior to the 15-year review is not practicable. Trigger E will measure the long-term development of riparian stands.

Trigger B. Trigger B was developed to measure the success of the NFHCP in meeting SHO #3, which is to create a net increase in canopy closure over streams over the life of the NFHCP. This also considers both harvested and un-harvested riparian areas and will be calculated using the same riparian plots established for Trigger E. Trigger B is related to the "Cold" biological goal, which is generally monitored under CAMP 3. But since the work will be done in conjunction with Trigger E, it is included in CAMP 2. Under this trigger, canopy closure is used as a measurable indicator for stream temperature. Trigger B will be considered tripped there is significantly less (alpha = 0.1) than a 2 percent per decade increase in canopy cover measured against the starting point in year 1.

Triggers E and B are based upon modeled expectations during the NFHCP effects analysis. It is important to note that normal stand development without harvest sometimes involves decreases in canopy closure or tree density, especially as those stands become more mature. These natural stand dynamics are, in fact, important for fish in that they represent the processes by which woody debris is naturally recruited to streams. Therefore, while these triggers are measurable, tripping them will not automatically mean that the biological goals are being compromised. This emphasizes the importance of using the Adaptive Management Pathway to interpret the tripping of triggers.

Hypotheses. CAMP2 consists of three research projects: 1) LWD Model Validation, 2) Influence of LWD on Fish Habitat, and 3) Trends in Riparian Conditions. The objectives, research questions, and hypotheses for each project are provided below.

Research Project 1: LWD Model Validation

Objective: To validate key assumptions used to forecast LWD loads under various harvest options.

Question 1a: Does hillslope angle influence the direction that trees fall in riparian areas?

H_o: Treefall angle is independent of hillslope angle.
H_a: Treefall angle significantly increases as slope angle increases.

Question 1b: Does the practice of selectively leaving trees that lean toward the stream have a significant influence on post-harvest LWD recruitment rates?

H_o: There is no effect of timber harvest on the proportion of trees within 50 ft of the stream that lean toward the stream, away from the stream, or that do not lean.
H_a: Timber harvest changes the proportion of trees within three lean categories and between two distance zones.

Question 1c: What are LWD depletion rates in streams of the Interior Columbia River Basin within the Project Area?

H_{o1}: Stream width has no significant influence on LWD depletion rates.
H_{a1}: LWD depletion rates increase as stream bankfull width increases

H_{o2}: Stream channel gradient has no significant influence on LWD depletion rates.
H_{a2}: LWD depletion rates are inversely related to stream gradient.

H_{o3}: The interaction of stream width and gradient has no significant influence on LWD depletion rates.
H_{a3}: The interaction of stream width and gradient *does* significantly influence LWD depletion.

Question 1d: How well does the FVS tree growth model apply to riparian forests?

This question is complex and does not lend itself to a single hypothesis test. The forest growth model (FVS) used to forecast LWD loads from different silvicultural treatments was developed largely based on growth data derived from upland forests. Environmental conditions in riparian areas may affect tree growth and mortality differently than in upland situations. A credible examination of this topic is a large effort that will require other cooperators. Numerous sites across a wide area will have to be sampled over a long timeframe (100+ years). To this end, a riparian forest dynamics cooperative is being organized, modeled after the upland stand management cooperative at the Univ. of Washington. Plum Creek is currently involved in this cooperative research effort, but there are no specific NFHCP commitments. Although results do not directly relate to a specific trigger, they do provide information of value to Plum Creek and other landowners that use the FVS growth model.

Research Project 2: Influence of LWD on Fish Habitat

Objective: To validate the relationships between LWD load and fish habitat (pool spacing, residual pool depth) for different channel types and geoclimatic regions (see introduction to Appendix AM-1 for description of geoclimatic regions).

Question 2: How is the influence of LWD upon the amount and quality of fish habitat (expressed as pools) affected by channel type (Montgomery and Buffington 1997) and geoclimatic region?

H_{o1}: Stream Channel Type (Montgomery and Buffington 1997) has no significant influence on the relationship between LWD load, pool spacing, and residual pool depth.
H_{a1}: Stream Channel Type *does* have a significant influence on the relationship between LWD load, pool spacing, and residual pool depth.

H_{o2}: Geoclimatic region has no significant influence on the relationship between LWD load, pool spacing and residual pool depth.
H_{a2}: Geoclimatic region *does* have a significant influence on the relationship between LWD load, pool spacing and residual pool depth.

H_{o3}: The interaction between channel type and geoclimatic region has no significant influence on the relationship between LWD load, pool spacing, and residual pool depth.
H_{a3}: The interaction between channel type and geoclimatic region *does* have a significant influence on the relationship between LWD load, pool spacing, and residual pool depth

Research Project 3: Trends in Riparian Conditions

Objective: To measure trends in tree conditions in riparian areas throughout the Project Area.

Question 3: Do riparian stands at the Project-Area level show improving trends in LWD recruitment potential and canopy closure under the NFHCP?

H_{o1}: The relative density and average diameter of the largest 88 trees per acre in riparian stands does not increase over time.
H_{a1}: There is a net increase in relative density and average diameter of the largest 88 trees per acre in riparian stands in sampled plots (Trigger "E").

H_{o2}: The average estimated canopy closure of sampled plots does not change through time.
H_{a2}: There is a net increase in canopy closure in sampled plots (Trigger "B").

These research projects are designed to address riparian topics in the forested portion of the Project Area. Null hypotheses and performance metrics for non-forested riparian areas (e.g. meadows) are described in Core Adaptive Management Project #4 (grazing).

Experimental design (Research Question #1a—Treefall Angle). This study is designed to test whether hillslope angle has a significant influence on angle of treefall. The results will be used to support determination of whether Trigger "D" is tripped. When modeling LWD loads to assess the impacts of logging on LWD recruitment for the NFHCP, random treefall angle was assumed. If steeper slopes increase the probability that a tree will fall toward the stream, then estimated LWD loads will increase. In their 1990 study, Van Sickle and Gregory found treefall angle to be random, however it is not clear whether their sample represented a wide range of hillslope angles. This study examines treefall angle in three hillslope classes: <30 percent, 30 to 60 percent, and >60 percent.

Methods. Twelve study sites will be selected for ease of access from among mature, unmanaged riparian stands where there is at least 1000 ft of stream with adjacent hillslopes in one of the three classes (GIS-derived slope information). USFS lands are included in the pool of potential study sites. Only sites where at least 300 ft of unmanaged forest border the channel will be used. This is to eliminate the potential effect of nearby timber harvest on treefall angle (e.g., via increased windthrow). At each site, the angle of the first 25 fallen trees >8" dbh encountered within 100 ft of the channel will be measured. Only the fallen trees that have their base within this area will be included. Four different drainages will be sampled for each slope class to obtain a total of 100 fallen trees per slope class. Angle of fall will be recorded relative to the axis of the stream channel, with a "zero" (reference) angle pointing upstream (Van Sickle and Gregory 1990). Only trees where the source can be determined and that have fallen naturally will be measured. Measurements will be made from the root pit of all fallen trees. More than 100 trees may need to be measured to ensure 100 trees will be measured in each slope class. Trees may be measured on one or both sides of the stream at each site. The distribution of treefall angles in each slope class (samples from all four drainages pooled) will be compared to a modeled random distribution using chi square analysis (Van Sickle and Gregory 1990). A significance level of 0.05 will be used in the chi-square tests.

Other parameters to be measured are the general aspect of the drainage (from maps); slope gradient at tree pit (nearest 5 percent, using clinometer); diameter of fallen trees (dbh, nearest 1", ocular estimate); and which side of the stream was studied (right bank or left bank looking downstream). These ancillary data may help explain departures from random fall direction (if found), and can help direct further investigation if desired (e.g., to refine slope class categories). Samples from twelve different drainages will provide insight into the spatial variability of treefall angle.

Use of Results. If treefall angle is found to be nonrandom, the treefall angle parameter in the LWD load model (Riparian-Aquatic Interaction Simulator [RAIS], version 3.0, Welty 1998) will be adjusted to produce revised LWD load forecasts for the significant slope class(es). If treefall angle is random, then no adjustments to this parameter will be made in revised model runs.

Timeframe. This study will be initiated and completed in year 1 of the NFHCP. Results will be available for the 5-year review report.

Experimental Design (Research Question #1b—Tree Lean vs. LWD Recruitment). This study examines the potential LWD recruitment consequences of leaving trees that lean toward the stream. It will be used to test the assumption used in NFHCP modeling that both pre and post harvest streamside trees do not have any tree lean. It will also be useful in measuring the effectiveness of the limited harvest provision that "trees leaning toward the stream or CMZ will be favored for retention. It is reasonable to assume that trees leaning toward the stream have a higher probability of reaching the channel than do trees that have no lean or that lean away from the channel. If timber harvest removes proportionately more trees with lower probability of stream entry, then logging impacts on LWD recruitment are reduced. The results will be used to support determination of whether Trigger "D" is tripped. The results will also aid in development of Mandatory and Cooperative Adaptive Management Responses.

Methods. Ten study sites (harvest units) will be selected randomly from among the study sites used for CAMP3. The direction of lean will be categorized for 100 trees >12" dbh within 50-ft of the stream channel in each harvest unit before harvest. Fifty trees will be measured in a zone between the streambank and 25-ft from the channel, and another 50 trees will be measured in a zone 25-50 ft from the channel. In each zone, the number of trees occurring in each of three categories of tree lean will be tallied: (1) leaning toward the stream (within the 180° arc facing the stream); (2) no apparent lean (estimated ±5 percent from vertical); and (3) leaning away from the stream (within the 180° arc facing away from the stream). Trees will be marked at their base with paint or tags. After harvest, the lean category will be recorded for any of the trees from the original tally that are still standing.

A chi square test of observed vs. expected frequencies will be performed using two distance zones (0-25 ft and 25-50 ft) and three categories of tree lean (lean toward the channel, no lean, lean away from the channel). Observed frequencies will be calculated for each combination of distance from channel and tree lean category as:

Number of post-harvest trees/ number of pre-harvest trees

The expected frequency will be calculated as:

16.67 / total sample size, or 0.167

This represents an even distribution of trees in each distance/tree lean combination and will therefore be the same for all cells. The chi square test will be performed using a significance level of 0.05.

Measurement of additional variables at the request of the Services, such as the quantity of downed wood in the CMZ, will be considered for inclusion in the final study design.

Use of Results. Results will be used to evaluate the benefits to LWD recruitment that are achieved by the practice of retaining trees that lean toward the stream. It is assumed that trees leaning toward the channel have a higher probability of being recruited to the channel when they fall. This is especially true for trees growing closer to the channel. This information can be used to support determination of whether Trigger "D" should be tripped. For example, the direction of fall bias can be calculated using data from this study and used via RAIS to forecast LWD loads from the measured stands before and after harvest. If the post-harvest stand data generates outcomes similar to unharvested stands, then this should reduce the need to trip trigger "D", even if data from other CAMP2 studies indicate otherwise. The results can also be used for development of Cooperative Management Responses. For example, assume the post-harvest measurements show that most, but not all trees that lean toward the channel are left in the 25-ft of the SMZ closest to the channel (Table 1). If trigger "D" is tripped for other reasons, then the information from this study would indicate that LWD loads could be increased by leaving more trees that lean toward the channel in the first 25 ft.

Table 1. Example data for pre- and post-harvest analysis of tree lean frequency. Data shown are the proportion of trees left standing after harvest, relative to their distance from the stream and direction of pre-harvest lean.

Tree Lean Category	Distance from the Channel	
	0-25 ft	25-50 ft
Lean Toward the Channel	$\frac{13^*}{17} = 0.76$	$\frac{10}{13} = 0.77$
No Lean	$\frac{20}{27} = 0.74$	$\frac{12}{27} = 0.44$
Lean Away from the Channel	$\frac{2}{6} = 0.33$	$\frac{0}{10} = 0.00$

* $\frac{\text{\# of trees after harvest}}{\text{\# trees before harvest}}$

Timeframe. This study will begin in the 2001 field season and is scheduled for completion within the first 3 years of NFHCP implementation. Results will be available for the 5-year reporting period. Timing of completion is dependent on the availability of harvest units.

Experimental Design (Research Question #1c—LWD Depletion Rates). This study examines the effects of channel size and gradient on LWD depletion rates in the Interior Columbia River Basin. The results will be used to support determination of whether Trigger "D" is tripped. Three channel widths, indexed by stream order (Strahler 1957), and four channel types (Montgomery and Buffington 1997) will be studied for ten years to determine whether a single average depletion rate is appropriate or whether channel size- or gradient-specific mean depletion rates are warranted.

Methods. Thirty-six sample sites will be randomly selected from among a pool of stream segments that represent combinations of channel types and sizes for perennial streams on Plum Creek lands. No other factors (e.g., geoclimatic region) will be used to stratify sampling sites. Stream order and provisional channel gradient for stream segments (~1000 ft minimum length) in the Project Area will be identified from USGS 1:24,000 topographic maps or GIS-based digital elevation models. The chosen channel size categories are small (2nd order or smaller), medium (3rd – 4th order), and large (5th order or larger). Once found, segments will be divided into 100-m sample reaches (via maps). These study reaches are 25 m longer than those used in Research Project 2 (below). This is because the 100-m reaches are easier to delineate on 1:24,000 maps and because no fish will be sampled in this study. Three 100-m reaches (sites) will then be randomly selected for each channel type/stream size combination (for 36 total sites). These will then be visited to verify that field gradients match map-based gradients. If the provisional gradient is confirmed, then the site is sampled. If not, then the remaining sites in the segment are randomized and a second reach is identified, visited to verify gradient, etc., until all sites are chosen.

At each 100-m site, all pieces of LWD with minimum qualifying dimensions of 10-cm diameter by 2-m length in zones 1-3 (Robison and Beschta 1990) are tallied, marked, tagged, mapped and measured. LWD pieces are marked with waterproof paint, tagged with aluminum tags, and measured for diameter (nearest ½", with calipers, at midpoint of exposed piece). Schematic maps are drawn by hand to roughly describe location and orientation of each tagged piece of LWD. This will aid in locating previously measured pieces during future visits. On the first visit, the upstream and downstream ends of the site will be monumented for future relocation. The same parameters will be measured during repeat visits. Newly recruited pieces are treated the same as the original pieces.

Depletion rates for each site will be calculated as the net loss of original LWD pieces through time, expressed as an average percentage loss per year.

Other variables to be measured at each site are channel gradient (nearest 0.5 percent, hand level), channel bankfull width (nearest foot), dominant substrate size, and riparian stand type (from Plum Creek 1999a). Stand type will only be recorded during the first visit.

Use of Results. The measured average LWD depletion rate (all sites pooled) will be used to revise original LWD forecasts. If depletion rates are found to differ among channel types or stream sizes, then separate LWD forecasts can be made to determine if Trigger "D" should be tripped only for these specific cases. If channel size is not found to influence depletion rates, then model re-runs will be made for a 20-ft channel width only (estimates were originally made for 10- and 30-ft channels).

Timeframe. Sites will be visited three times, in years 1 (2001), 5, and 10. Some sites may also be visited in years 2 and 8 are to ensure that LWD pieces retain their marks and tags. Depletion rates for 5- and 10-year periods will be available for the 5- and 10-year reports, respectively. These time periods should be adequate to obtain reasonable estimates of LWD depletion rates (McHenry et al. 1998).

Trigger D Calculation. Findings from some studies under Research Project #1 will be used to re-estimate LWD loads expected from the six management options described in Plum Creek (1999a). Other sources (e.g., published research) may provide additional information that can be used in revising estimates. Examples of information that may be used are:

- Rates of LWD inputs from other sources besides stand-suppression mortality (e.g., bank erosion);
- Initial in-channel LWD loads in Project Area streams;
- Validity of Rustagi and Loveless (1991) tree taper function for eastside trees, etc. (see Plum Creek 1999a, Table 15).

If the combined effect of revised parameters produces an estimated average LWD load at 30 years that is more than 20 percent beyond the original weighted-average estimate for all stand types combined, then Trigger "D" is tripped and the Adaptive Management Pathway is initiated. If none of the variables used in the model change as a result of the assumption validation studies, then the LWD load model will not be re-run.

While trigger D will be calculated based upon all stand types considered together, if the model is run with new assumptions, the information will be reported to the Services by stand type to support potential cooperative management responses or a proposal to modify triggers.

Experimental Design (Research Project #2—Influence of LWD on Fish Habitat). The information from this study will be used to inform Plum Creek and the Services about biological relevance if the CAMP2 triggers are pulled based on data obtained from other projects, or to support a proposal for a Cooperative Management Response. The information obtained in this project does not directly relate to a trigger.

An underlying assumption of the NFHCP riparian management commitments is that different channel types respond differently to LWD (Montgomery and Buffington 1997), and that fish habitat quantity and quality reflects these differences (Plum Creek 1999a). This assumption will be tested through research to validate the relationships between channel type and LWD load (pieces per 1,000 ft., minimum qualifying dimensions of 10-cm diameter and 2-m length), and fish habitat (pool frequency and residual depth) within and among geoclimatic regions. Fish abundance (number per unit surface area) will also be measured at each site to provide information regarding biological relevance of any identified relationships or trends between LWD and habitat variables. Ten 75-m stream reaches will be sampled for each Channel Type and Geoclimatic Region combination (n= 120 sites, Table 2). Each site will be visited once.

Table 2. Experimental design for Two Factor multiple analysis of variance (MANOVA)

Geoclimatic Region	Channel Type (gradient class)			
	<1.5%	1.5% - 3%	3-6.5%	>6.5%
Wet alpine glaciated	Dependent variables = LWD, Pools	N = 10 sites	N = 10 sites	N = 10 sites
Wet continental glaciated	N = 10 sites	N = 10 sites	N = 10 sites	N = 10 sites
Wet fluvial	N = 10 sites	N = 10 sites	N = 10 sites	N = 10 sites

Methods. Sample sites will be randomly selected from among a pool of stream segments that represent channel types for perennial fish-bearing streams on Plum Creek lands in three major geoclimatic regions. Stream size may have an important influence on depletion rates. This study will control for stream size by selecting only streams between 10 and 30 ft bankfull width. This represents the size of fish bearing streams commonly found in the Project Area. These will be indexed by stream order, assuming 2^{nd}-4^{th} order streams encompass the desired 10-30 ft size range. Stream order and provisional channel gradient for stream segments (~1,000 ft minimum length) in the Project Area will be identified from USGS 1:24,000 topographic maps or GIS-based digital elevation models.

Once found, twenty segments will be randomly selected for each channel type/geoclimatic region combination. The first ten of these segments will then be visited to verify that field gradients match map-based gradients, that stream widths are between 10 and 30 ft, and that fish are present. If the provisional gradient and size are confirmed and fish are present, then a channel survey reach will be placed in the center of the segment. If not, then the segment will not be sampled and the next randomly chosen segment will be visited to determine sampling suitability. This will continue until all sites are chosen and all cells of the MANOVA design are filled.

Within each segment chosen for sampling, sample sites (reaches) will be established to measure channel and fish variables. For channel (and habitat) variables, a survey reach will be established that is scaled to the size of the stream. This ensures the variability in channel and habitat features will be reasonably well accounted for. A minimum length of 250-ft (75 m) and a maximum length of 20 times the bankfull channel width (up to 600 ft for 30-ft wide channels) will be used. Fish survey reaches of 250-ft (75 m) will be nested within the larger channel survey reaches. This shorter reach length is chosen to reduce stress to fish held during multiple-pass removal sampling.

An attempt will be made to ensure that a range of wood loads is represented in each channel type and geoclimatic region. When provisional sites are inspected for their suitability as described above, an ocular estimate of wood loads will be made. Sites will then be chosen to provide roughly equal sample sites among three wood loading levels (pieces per 1000 ft): Low <21, moderate 21-136, high >136 pieces. These were derived from the pooled LWD data from comparable studies of unmanaged streams in the Interior Columbia River Basin (Plum Creek 1999a). Low levels represent loads less than one standard deviation below the mean, moderate represents within one standard deviation of the mean, and high represents more than one standard deviation above the mean.

At each site LWD, fish habitat, and fish utilization will be measured. All pieces of LWD with minimum qualifying dimensions of 10-cm diameter by 2-m length will be tallied within and above the bankfull channel area (zones 1-3, Robison and Beschta 1990). Diameter at each end will be measured to the nearest ½”. The surface area of pool habitat (all pools and those with minimum qualifying dimensions) and residual pool depths will be measured using methods of Pleus et al. (1999). Fish will captured via standard multiple-pass electrofishing procedures using block nets. Captured fish will be identified to species and measured to the nearest mm fork length. Sampling will be conducted during low flow conditions of summer through fall.

Additional information on characteristics of riparian areas, channels, and water chemistry will be collected to aid interpretation of the analysis of variance results. Riparian characteristics are tree density, quadratic mean diameter, basal area, height, species mix, size distribution; habitat type (Pfister et al. 1977), and stand type (from Plum Creek 1999a). This information will be obtained by measuring 100 percent of the trees (>1” diameter dbh) in the 50 ft by 250 ft area bordering each stream reach sampled for fish. If stands contain high densities of small trees (e.g., regenerating plantations), stands will be sub-sampled using ten 1/100th acre plots evenly distributed along the channel.

Channel characteristics are average gradient (measured with hand level); bankfull width (nearest foot); substrate size; and stream power index (the product of bankfull depth, bankfull width, and mean channel slope [%]).

Measured water chemistry parameters are total alkalinity and conductivity (measured with titration and electronic probe, respectively).

Standard MANOVA analyses will be used to test null hypothesis using a significance level of 0.05.

Use of Results. These data will contribute to determination of causal linkages and biological relevance, but will not be used to determine if a trigger is tripped. These data can also be used to support Cooperative Management Responses. For causal linkages, these data will be used to validate and refine the assumption that different channel types have inherently different sensitivities to LWD gain or loss. For example, consider the case where it is found that within the wet continental glaciated geoclimatic region there is as strong a relationship between LWD and pools in step-pool channels as there is in plane-bed/forced pool-riffle channels. Also, fish density increases with increasing pool density. Based on this information, a Cooperative Management Response could be proposed to increase the riparian commitment on step-pool channels in wet continental glaciated geoclimatic regions to a 25-ft no entry (or other option). If the same response is observed across all three dominant geoclimatic regions and a Cooperative Management Response is proposed, the proposal could include the entire Project Area irrespective of geoclimatic region.

For biological relevance, fish data will be used in conjunction with published research to aid interpretation of the biological relevance of different LWD loads among channel types and geoclimatic regions. It is expected that fish abundance in a geoclimatic region will reflect at least the pool abundance data, and possibly the LWD abundance data. If so, then this information will be used to corroborate inferences based on LWD-habitat relationships. If not, then either the fish are not responding to the measured habitat features, or there are extraneous factors that mask their response.

To illustrate the use of fish abundance data, consider the situation where resident cutthroat densities are found to respond the same as bull trout to LWD-formed pool abundance in plane-bed/forced pool-riffle channels. If at the same time the expected relationship between LWD and pools in plane bed-forced pool-riffle channels is confirmed, then a Cooperative Management Response could be proposed to increase riparian prescriptions in Tier 2 drainages on this channel class. Another example is where the expected relationship between LWD and fish habitat in plane-bed/forced pool-riffle channels is demonstrated in this study, but the fish data showed strong populations independent of the habitat features. In this case, when properly interpreted to include the context of the study sites, it could be shown that a Cooperative Management Response to change to riparian commitments is not warranted.

Timeframe. This study is anticipated to begin in year 2 of the NFHCP and take up to 3 years to locate and measure all 120 sites. The results and their interpretation will be available for the 5-year NFHCP review.

Experimental Design (Research Project #3—Trends in Riparian Conditions). This study is designed to monitor LWD recruitment potential throughout the Project Area over the life of the NFHCP. The results will be used to calculate whether Trigger E is tripped. Trends in canopy closure for Trigger B will also be tracked and evaluated with this study. The design entails establishment of a network of permanent riparian plots distributed randomly throughout the Project Area, with periodic measurement over time. The relative density and quadratic mean diameter (qmd) of the largest 88 trees per acre in riparian stands will be used as an index of

LWD recruitment potential, with the assumption that denser and larger trees in riparian areas through time improves recruitment potential for LWD in adjacent streams.

Methods. One thousand 1/20th acre plots will be selected from throughout the Project Area east of the Cascades Crest via random selection. Sample locations will be drawn from a pool of perennial stream miles on Plum Creek lands, excluding non forested land and Higher and Better Use lands identified in Plum Creek's timber inventory database (January 1, 2000 baseline). Square mile sections of Plum Creek lands will be selected randomly within each planning area basin east of the Cascades Crest. The number of samples will be in rough proportion to the Plum Creek acreage within each planning area basin. Sections with less than 0.5 mile of perennial streams will be excluded. A minimum of four and maximum of 10 plots per section will be established. Plots will be located in streamside stands with plot center established at 27 feet from the bankfull width or Channel Migration Zone (if present). The following table lists the data to be collected at each plot. Tree level data will be collected on all trees >1" DBH and tree heights may be sub-sampled.

Plot centers will be monumented with rebar to aid relocation. All trees within each plot will be painted. Timber cruisers will also note if the riparian area is within a harvest project conducted since the previous measurement.

Data will be post-stratified by stand type and the estimated proportion of Project Area Stream Miles represented by each stand type will be calculated.

Information for triggers E and B will be averaged over all 1000 plots and then evaluated with trend analysis. The following data will be collected in each plot.

Plot Level Information	Tree Level Information
Plot Number	Species
Location	Live/Dead Status
Stand Number	DBH
Measurement Date	Trees per plot
Aspect	Total Height
Slope	
Elevation	
Habitat Type	
Logging Activity	

Use of Results.

Trigger E. At the 15, 20 and 25 year reporting periods, the **relative density** and **quadratic mean diameter** will be calculated for the **largest 88 trees per acre** from all plots. If both metrics decline or stay the same when compared with the starting values at year 1, then the trigger will be considered tripped and the adaptive management pathway will be initiated. Other data collected will aid in the determination of biological relevance and will help to diagnose causal linkages. The ability to separate out riparian stand performance associated with adjacent harvest versus no adjacent harvest will provide the ability to evaluate minimization of impacts separately from recovery in riparian stands that are not buffers to a harvest unit.

Trigger B. Canopy closure will be calculated using FVS based on plot data taken in years 10 and 20. Trigger B will be considered tripped there is significantly less (alpha = 0.1) than a 2 percent per decade increase in canopy cover measured against the starting point in year 1. Should trigger B be tripped, evaluation under the adaptive management pathway will be considered in conjunction with CAMP 3 data and the results of trigger A calculation.

Timeframe. Sites will be measured five times over the 30-year life of the HCP. Initial plot establishment will be conducted before the end of year 1 of the NFHCP and data will be included in the final study design for CAMP 2 which will also be complete by the end of year 1. Subsequent measurements will be taken in years 10, 15, 20, and 25.

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3. Core Adaptive Management Project #3: Evaluation of NFHCP Effectiveness at Minimizing Stream Temperature Increases from Streamside Harvesting

Introduction. A Biological Goal of Plum Creek's Native Fish Habitat Conservation Plan (NFHCP) is to

> "*Protect stream temperatures where they are suitable for fish, and contribute to restoration of temperatures where they are unsuitable as a result of past Project Area management*."

To help meet this goal, the NFHCP further defined three Specific Habitat Objectives:

1. Minimize impacts to canopy closure and changes in channel morphology resulting from riparian timber harvest and grazing;

2. Improve the ability of riparian vegetative communities to provide canopy closure over streams through passive and active restoration; and

3. Create a net increase in canopy closure over streams.

Numerous NFHCP riparian, grazing, and restoration commitments were crafted to achieve these three Specific Habitat Objectives. These include commitments Rp1-Rp9, G1-2, G4, and Lg2.

As part of the NFHCP, a "trigger" was developed to measure the success of attaining Specific Habitat Objective #1. If this trigger is "tripped," the adaptive management pathway is initiated to evaluate if NFHCP conservation commitments should be changed. This trigger is as follows:

> *A statistically significant (alpha = 0.1) increase of 1.0 °C in maximum weekly average temperature [Trigger "A"].*

The purpose of Core Adaptive Management Project 3 (CAMP 3) is to investigate reach- and watershed-scale changes in stream temperature associated with streamside harvesting under the NFHCP. Results from this study will be used to guide adaptation of the Plan through time. Specifically, this project will provide the following information for the NFHCP:

1. Provide effectiveness monitoring data to determine if Trigger "A" should be tripped at 5-year reviews.

2. Inform the need to change the trigger over time. At the outset of the plan, Trigger "A" will be based on a pooling of all sample sites. Further investigation may reveal specific circumstances where harvesting is increasing stream temperature, but this increase is not reflected in the mean response. Trigger "A" could be modified based on this information.

3. Provide data that could be used in crafting Cooperative Management Responses under adaptive management.

4. Provide information on the biological relevance of observed temperature changes should Trigger "A" be tripped and the Adaptive Management Pathway invoked.

5. Aid in documenting and determining the source of observed temperature changes should Trigger "A" be tripped and the Adaptive Management Pathway invoked.

Hypothesis. The primary question to be answered in this study is to what degree streamside timber harvesting affects summer stream temperatures. The specific null hypothesis being tested is as follows:

H_o = Reach-scale temperatures change less than 1 °C following streamside timber harvesting.

The alternative hypothesis is then:

H_1 = A statistically significant reach-scale temperature increase of 1 °C or more following streamside timber harvesting (Trigger "A"). The allowable Type 1 error will be 0.1 (alpha=0.1), or a confidence interval of 90 percent.

If the monitoring experiments indicate that the null hypothesis should be rejected, Trigger "A" will be tripped.

Experimental Design. Stream temperatures will be measured for one summer before, and after, streamside harvesting. This will involve placement of continuous temperature recorders in the stream at the upper and lower boundaries of the harvest unit. These are represented as Thermographs 2 and 3 in Figure 1. An additional thermograph (1) will be placed approximately 300 meters above the upper boundary of the harvest unit. This will tell us whether the stream is warming or cooling as it enters the harvest area.

Watershed-scale temperature changes will also be investigated by examining downstream recovery (or persistence) of reach-scale stream temperature changes. This will be accomplished by using two additional thermographs that will be installed below the downstream boundary of the harvest unit (Thermographs 4 & 5). Thermograph 4 will be located approximately 150 meters downstream of the lower boundary of the harvest unit while Thermograph 5 will be located 300 meters below the downstream boundary of the harvest unit (or 150 meters below Thermograph 4).

Thermographs to be used in this study are Optic StowAway™ and StowAway TidBit™ temperature loggers manufactured by Onset Computer Corporation (Pocasset, MA). These thermographs have a range of –0.5 °C to +37 °C, and have a rated accuracy of ± 0.2 °C at +21 °C. Prior to deployment, thermograph readings would be verified in an ice bath and against a lab-grade thermometer. This will also be done immediately following thermograph retrieval in the fall.

Temperature loggers will be deployed by July 1st and be retrieved after mid-September of the same year. Based on local experience with stream temperature regimes, this should ensure that maximum temperatures are captured. All thermographs will be programmed to record every half-hour through the monitoring period. Temperature loggers will be placed in a location in the stream where water exchange is rapid, but where risk of de-watering (exposure to air) is low. These are most often shallow lateral scour pools.

Harvest units will border at least 300 meters of fish-bearing perennial stream channel. This distance was chosen to ensure that water temperatures would have sufficient time to respond to surrounding conditions. A review of the literature suggests that smaller mountain streams should respond within this distance (see Zwieniecki and Newton 1999).

From the raw thermograph data, the following temperature metrics will be compiled for each summer at each survey site:

- **Maximum Daily Average Temperature (MDA)—**This is the warmest daily average water temperature recorded during a given year or survey period.
- **Maximum Daily Maximum Temperature (MDM)—**This is the warmest daily maximum water temperature recorded during a given year or survey period.
- **Maximum Weekly Average Temperature (MWAT)—**This is the mean of daily average water temperatures measured over the warmest consecutive 7-day period (typically during a given year).
- **Maximum Weekly Maximum Temperature (MWMT)—**This is the mean of daily maximum water temperatures measured over the warmest consecutive 7-day period (typically during a given year).
- **Maximum Diurnal Fluctuation—**This is the maximum measured difference between a daily maximum temperature and daily minimum temperature during a year or survey period.

Covariate Data Collection. A variety of covariate data will be collected as part of this study, including the following:

- Air Temperature (^{o}C)
- Elevation of stream (m)
- Azimuth of stream (^{o})
- Bankfull and wetted stream width (m)
- Summer low flow stream discharge
- Stream depth (m)
- Stream gradient (%)
- Channel type [Montgomery and Buffington 1997, Rosgen (1994)]
- Ecoregion
- Geologic District

- Dominant Geo-climatic Region (an amalgamation of geologic district, geomorphology, and climate)
- Harvest prescription (NFHCP commitment)
- Whether the harvest occurred on one or both sides of the perennial stream
- Canopy Cover (%) (Platts et al. 1989; Schuett-Hames et al. 1994)
- Plum Creek riparian stand type (e.g., H9, H15, T9, T15)
- Riparian habitat type (Hansen et al. 1995)
- Change in riparian stand structure attributes (e.g., % harvest removal, change in basal area, etc.)
- Microclimate transect data on a sub-set of temperature sites

These covariates were selected based on a Pacific Northwest study that evaluated which factors explained most of the variability on maximum stream temperatures (Sullivan et al. 1990). Use of covariate data will be discussed later in this study plan.

Criteria for Site Selection. To be a candidate for this study, sites must meet the following criteria:

- Harvest occurs anywhere in the NFHCP Project Area. This includes Plum Creek lands in Montana, Idaho, and southwestern and south central Washington.
- Harvest will border at least 300 meters of fish-bearing perennial stream (along one or both sides).
- The monitored stream must be fish-bearing and perennial for its entire length through the harvest area and for at least 100-meters above the harvest area
- Harvest will occur during the fall, winter, or spring. This will ensure the minimum amount of time between pre- and post-treatment monitoring
- There will be no other activities occurring immediately upstream or immediately downstream of the treatment area for the duration of the study

It is expected that approximately 8-15 harvest areas in the Project Area would meet these criteria each year. No more than ten sites will be needed for initial sampling in any given year (see below). Of the annual available candidate sites, sampling sites will be selected so as to maximize the potential variance of independent covariates. Maximization of this variance will complement the mid-course statistical analyses (described below) by providing the independent factor variance necessary to ascertain if any patterns or trends in relationships exist (i.e., cluster analyses and correlations).

Data Analysis. Pre- and post-harvest longitudinal profiles of stream temperature metric data will be plotted and visually evaluated for each sample site. The statistic proposed to evaluate change due to harvesting will be the ratio of the sum of the temperature (metric) at each site as shown in Equation 1 (with the upstream "control" variable in the denominator). An equation to calculate a confidence interval on a ratio was developed by Miller (1986). This equation is appropriate for samples with unequal variances and is shown in Equation 2. A significant difference exists if the 90 percent confidence interval of the ratio does not capture the number 1.

To illustrate this approach, temperature data were compiled from 12 streams on Plum Creek forestland in the Pacific Northwest (mostly east of the Cascade Crest). For each stream, temperature data are available from two sites (pairs) that are separated by 300 to 600 meters. Summary temperature metrics from the paired data at each site are presented in Table 1. Using the equation shown above, 90 percent and 95 percent confidence intervals were placed on each ratio (Table 2). These analyses indicate that there is no significant difference between temperatures at upstream and downstream locations. These results were checked against those from paired t-tests. The paired t-tests also indicated no significant difference between upstream and downstream temperatures. However, the t-tests had low power (~0.10). This is because the mean difference between upstream and downstream locations was very small (ranged from 0.09° to 0.22°C).

Mid-Course Statistical Analyses. After the third and fourth year of data collection, we will use bivariate plots to examine relationships between water temperatures and the various independent variables. We will also test relationships by calculating correlations among variables. Depending on these relationships, we will use cluster analysis to group sampling sites with similar attributes into unique clusters based on the variables measured at each site. Stepwise multiple discriminant analysis can then identify which variables are most important statistically in determining differences among clusters. These analyses will assist in directing subsequent research as part of CAMP 3.

Sample Size Estimation. The number of samples needed to detect a 0.5° and 1.0°C mean difference between upstream and downstream locations were calculated based on the 12 sites in Table 1. Because we are unaware of a way to calculate power and sample sizes with ratios, we used power analysis for paired t-tests. Sample sizes were calculated for a power of 0.80 and alphas of 0.05 and 0.10, using the standard deviation of the difference between upstream and downstream locations for the East Cascade sites (Table 3).

This analysis indicates that detecting a mean difference of 1.0 °C for all metrics would require less than 10 samples. Smaller mean differences (e.g., 0.5°C) would require more samples. From this analysis, a sample size of 10 should adequately find differences of 1.0°C. As will be discussed later, the final sample size will be 30 to allow for exploration of specific situations where temperature increases may be significant.

Fish Habitat Utilization (Biological Relevance Data). Subject to acquisition of applicable state and federal collection permits and their provisions, habitat utilization data will be collected on all temperature research sites initiated in 2000 and after. This will be conducted on the lower 100 meters of both the treatment and control reaches (The control reach would be immediately above the treatment reach). For each 100-meter reach, block nets will be established. Multiple pass depletion electrofishing will then be performed to obtain estimates of fish species composition, size/age class distribution, and population density (individuals per unit surface area). Data will be collected during late July or August of the treatment year and late July or August of the post treatment year. Habitat utilization data will be collected in late July or August since this is the time period when temperature stress on fish is likely to be highest and avoidance of sub-optimal habitats would be expected. If Trigger "A" is tripped, these data will be used in conjunction with other relevant scientific information to determine if the observed increases in water temperature are meaningful in terms of habitat availability and potential physiological stress (e.g., biologically relevant).

Microclimate Data Collection. In addition to stream temperature data, temperature and relative humidity transects will be placed in three study areas. In addition to other covariate data, microclimate transect data could aid in explaining observed stream temperature changes.

For each of the three study sites, two transects perpendicular to the stream will be installed. One will cross the stream at the center of the harvest unit. The second transect will be installed in a fully forested riparian stand upstream of the harvest unit and will serve as a control.

Temperature and humidity sensors will be placed along transects running perpendicular to the stream (Figure 2). One sensor will be suspended immediately above the stream channel. The second set of sensors would be placed 3 meters from the ordinary high water mark on each side of the stream. The third set would be located 7.6m (25 feet) from the ordinary high water mark. The fourth set would be located 15m from the ordinary high water mark. For a Montana SMZ harvest, this would be the outer edge of the harvest zone. The last set of sensors would be placed 45 meters away from the stream and be located well into the harvest unit adjacent to the riparian buffer. Other details of the microclimate variable data collection effort will be worked out in the coming months.

Due to the cost of this study, Plum Creek will fund measurement of three sites (6 transects). If additional cost-sharing monies were available, additional microclimate transects could be installed.

Trigger Calculation and 5-Year NFHCP Review. Prior to the 5-year review, the entire data set will be analyzed to determine if Trigger "A" should be tripped. The ratio estimator approach discussed in the ***Data Analysis*** section above will be the method used to determine if the null hypothesis should be rejected and the trigger tripped. Should the trigger be tripped, fish habitat utilization data collected during the project (and other relevant scientific information) can be used to determine the biological relevance of the observed change. Additionally, covariate data could help specifically identify the specific circumstances that led the tripping of Trigger "A."

Should Trigger "A" not be tripped at the 5-year review, a Cooperative Management Response could be proposed should specific situations be identified where adverse temperature changes were occurring.

Timetable for Study

Year 1 (1999)—This year served as a pilot temperature study. Pre-harvest data were collected on three sites. Two of these sites were harvested in the winter of 1999-2000 and will be re-measured in summer of 2000. The site that was not harvested in winter 1999-2000 will be measured again this coming summer (two years of pre-treatment data) and harvested in winter 2000-2001.

Year 2 (2000)—Ten sites that meet the selection criteria will be randomly selected for pre-treatment monitoring this year. In addition, microclimate transects (temperature and relative humidity) will be placed in one of these harvest areas.

Year 3 (2001)—Year 2000 sites will be re-measured (post-harvest). In addition, eight new sites will be initiated for monitoring, including two additional microclimate sites. In the fall of 2001, mid-course statistical analyses will be performed on results of the completed treatment studies to identify the variables most affecting temperature change. Results of this analysis will direct Year 4 monitoring.

Year 4 (2002)—Year 2001 sites will be re-measured (post harvest). In addition, eight new sites will be initiated for monitoring. Selection of these sites will be based on the statistical analysis performed after Year 3. Following Year 4 data collection, additional mid-course statistical analyses will be performed on results of the completed treatment studies to identify the variables most affecting temperature change. Results of this analysis will inform a decision on whether additional sites need to be monitored in Year 5.

Year 5 (2003)—Year 2002 sites will be re-measured (post harvest). It is anticipated that four new sites will be added based on the statistical analyses performed after Year 4.

Year 6 (2004)—Re-measure remaining five sites from 2003. Do complete statistical analyses on data collected to date and write report for 5-year NFHCP review, including a calculation on Trigger “A.”

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Equation 1. Equation for calculating the ratio

$$\textbf{Ratio} = \frac{\sum_{i=1}^{N} T_i}{\sum_{i=1}^{N} C_i}$$

$Where:$

T_i = temperature (metric) at a treatment site

C_i = temperature (metric) at a control site

i = a given sample site

N = total number of sampled sites

Equation 2. Confidence interval for ratios with unequal variances (Miller 1986).

$$\textbf{Confidence Interval} = \frac{\overline{C}\overline{T} \pm \sqrt{\overline{C}^2\overline{T}^2 - (\overline{C}^2 - t^2 {S_c}^2)(\overline{T}^2 - t^2 {S_t}^2)}}{(\overline{C}^2 - t^2 {S_c}^2)}$$

$Where:$

$\overline{T}$ = treatment sample mean

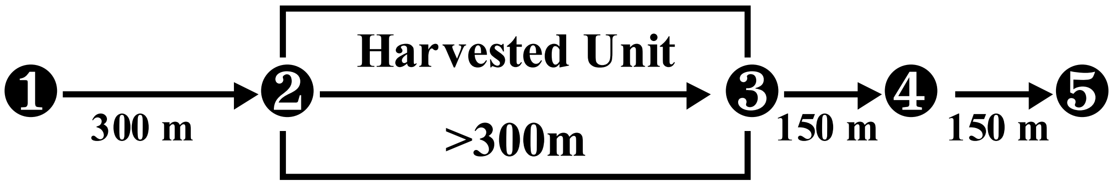
$\overline{C}$ = control sample mean

S_t = standard error of treatment mean

S_c = standard error of control mean

t = student's t value

Figure 1. Illustration of thermograph placement in relationship to harvest unit boundaries (after Zwieniecki and Newton 1999). Harvest units may border one or both sides of the stream.



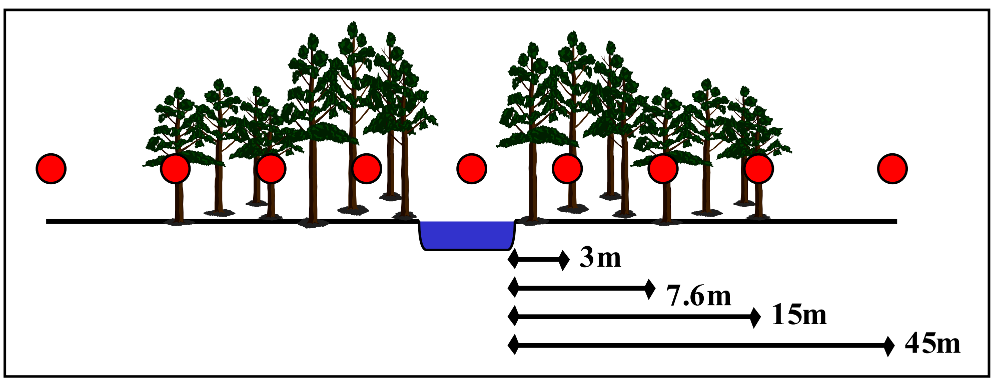


Figure 2. Illustration of microclimate transects through riparian harvest areas.

Table 1. Temperature metrics complied from data at 12 sites east of the Cascade Mountain crest. At each site, temperatures were recorded at an upstream (control) site and a downstream (test) site.

	Control (Upstream)				Test (Downstream			
Site	MWMT	MWAT	MDM	MDA	MWMT	MWAT	MDM	MDA
1	13.80	11.00	14.80	11.80	12.10	10.10	12.90	10.80
2	12.43	11.09	13.40	12.01	11.97	10.51	12.80	11.42
3	11.09	10.05	11.87	10.65	12.03	11.19	12.69	11.71
4	7.47	6.91	7.82	7.30	8.39	7.75	8.92	8.27
5	11.81	11.32	12.10	11.60	11.47	11.09	11.70	11.42
6	14.23	11.28	14.80	11.99	13.43	11.48	13.87	11.83
7	13.15	10.90	13.81	11.61	14.60	11.81	15.38	12.53
8	15.14	11.43	15.90	12.32	13.23	11.23	13.91	12.00
9	9.40	9.08	9.40	9.08	8.99	8.30	9.49	8.77
10	16.30	14.60	17.20	15.00	15.40	14.10	15.80	14.70
11	9.90	9.30	10.20	9.60	10.60	10.00	11.00	10.30
12	14.40	12.10	15.60	12.60	14.90	12.50	15.80	13.00
Sum	149.12	129.06	156.90	135.56	147.11	130.06	154.26	136.75
Mean	12.43	10.76	13.08	11.30	12.26	10.84	12.86	11.40
SD	2.60	1.86	2.86	1.96	2.21	1.72	2.29	1.75

Table 2. Ratios and both the 90% and 95% confidence intervals around the ratio of means, and significance of temperature data from upstream (control) and downstream (test) locations.

Metric	Alpha	Ratio (T/C)	Lower CI	Upper CI	Significant?
MWMT	0.05	0.99	0.83	1.18	No
	0.10	0.99	0.85	1.14	No
MWAT	0.05	1.01	0.87	1.17	No
	0.10	1.01	0.89	1.14	No
MDM	0.05	0.98	0.82	1.18	No
	0.10	0.98	0.85	1.14	No
MDA	0.05	1.01	0.87	1.17	No
	0.10	1.01	0.89	1.14	No

4. Core Adaptive Management Project #4: Long-term effectiveness of Plum Creek's Grazing BMPs

Introduction. The Grazing BMPs (described in G1) and other range management commitments specifically relate to NFHCP Biological Objectives #1 and #8. This Experimental Management study will build a knowledge base by which the long-term effectiveness of Plum Creek's Grazing BMPs can be evaluated and will serve as a basis for BMP modifications (in the event that conditions do not improve as a result of BMP implementation).

A network of monitoring plots will be established to evaluate the long-term effectiveness of Plum Creek's Grazing BMPs at maintaining or improving riparian conditions and fish habitat. Various grazing treatments will be assigned to study plots and results monitored at year 2, then every 5 years thereafter.

Information obtained from the plots will be used to determine if adaptive management changes in the NFHCP should be triggered, and if so, isolate the specific practices that require modification.

Purpose and Objectives. To obtain information on the overall trend in riparian condition and fish habitat in the NFHCP area, and to relate this trend to implementation of Plum Creek's Grazing BMPs and other more restrictive management approaches such as fencing.

Hypothesis. Null Hypothesis: There is no difference (alpha = 0.1) in riparian and physical habitat variables (to be determined) between control and treatment areas.

Alternative Hypothesis: There is a difference in riparian and physical habitat variables between control and treatment areas, but there is a one-directional response (that is, net improvement).

Approach. Fish use in streams in the NFHCP area is concentrated in stream gradients less than 4 percent. These same stream reaches tend to be most sensitive to grazing disturbance. Using Plum Creek's Geographic Information System (GIS), we will identify all perennial stream segments in grazing allotments that have a gradient less than 4 percent. Then, through conversations with Plum Creek foresters, scientists, and range managers, segments that are known to be moderately-to-severely impacted by cattle grazing will be identified. Another approach that could be used is the University of Montana's Riparian Health Assessment. Once identified, approximately 20 of these stream segments will be randomly selected for long-term monitoring.

Reach Level. Each stream reach selected will be assigned one of four treatment types (five reaches each):

- Season-long grazing without BMPs
- Season-long grazing implementing Plum Creek's Grazing BMPs (BMP System 1)
- Season-long grazing without BMPs

- Season-long grazing implementing Plum Creek's Grazing BMPs (BMP System 1)
- Short-duration or "controlled" grazing (e.g., riparian pasture) implementing Plum Creek's Grazing BMPs (BMP System 2)
- No grazing (exclosed to cattle grazing via fencing)

Stream reaches will be re-sampled at year two, then every 5 years thereafter. Data to be collected include stream (fish habitat) characteristics (e.g., pool depth, percent surface fine sediment, channel width, percent over-hanging banks, percent cover, etc.), riparian characteristics (e.g., vegetation composition, vegetation type, etc.), and the degree of fish habitat utilization (e.g., species, size class, abundance).

The exact study design will be developed in cooperation with the Services and other experts.

Use of Results. Data will be used to examine effects among the various treatment types and document the direction and magnitude of change in habitat variables. Results of this study will be used as a basis for modifying the Grazing BMPs through time. This could occur as soon as 5 to 10 years after inception of the project.

Timetable. First year data would be collected within two years after implementation of the NFHCP. It is envisioned that these data would be collected at year 2 of the study, then every 5 years thereafter for at least 20 years

IV. Use of CAMP Results in Changing Management

The Adaptive Management Pathway specified in commitment AM2 specifies level of scientific rigor for evaluating science-based triggers to determine whether a management response is warranted and to guide development of that response. The following tables (AM-1-6 through AM-1-8) provide CAMP specific detail for meeting Adaptive Management Pathway checkpoints.

TABLE AM-1-6
Use of CAMP1 Results in Adaptive Management

Adaptive Management Process Step	Use of CAMP1 Results in the Adaptive Management Pathway
Trigger	**Trigger C (SHO6)—Is there a net sediment delivery reduction considering both new road construction and old road upgrades?** Trigger "C" will be tripped if the pro-rated sediment reduction calculated across the Project Area is 30% or less, which is significantly less (at approximately 1 standard deviation) than the average weighted reduction of 49% calculated in the effects analysis The pro-rated reduction will require a 10% reduction in net sediment delivery at the 5-year review, 20% by the 10-year review, and 30% by the 15-year review. If the observed reduction is less than the pro-rated reduction, then the trigger will be tripped and the adaptive management pathway invoked. For purposes of determining if Trigger C should be tripped, net sediment reduction from roads at the 5-, 10-, and 15-year project reviews will be calculated as follows: 1. Pre-NFHCP baseline sediment delivery from road surface erosion will be determined by identifying all road segments in the 17 watersheds used in the original DEIS effects analysis for which Plum Creek has direct or shared responsibility for under the NFHCP. Pre-NFHCP sediment delivery rates will be totaled for all of these segments (in tons/year) and serve as the baseline sediment delivery for comparison. 2. Immediately prior to the 5-, 10-, and 15-year project reviews, these road segments will be re-inventoried, along with any new Plum Creek roads in these watersheds (constructed since the NFHCP was initiated) using the Road Sediment Delivery Analysis (RSDA) procedure (See NFHCP Commitment R10). This inventory will also include any roads abandoned under the NFHCP. After totaling sediment delivery from all road segments, this re-assessment will yield the current projected sediment delivery to streams (in tons/year) from the same road segments used in the baseline analysis, plus any newly-constructed roads. 3. The sediment delivery calculated in Step 2 above will be subtracted from the baseline inventory in Step 1 above to determine the absolute net change in sediment delivery since NFHCP initiation (in tons/year). This difference is then divided by the baseline delivery rate (Step 1) to yield the percentage reduction from baseline conditions. The percentage reduction calculated in Step 3 will then be compared with the pro-rated trigger value. The pro-rated reduction will require a 10% reduction at the 5-year review, 20% by the 10-year review, and 30% by the 15-year review. If the observed reduction is less than the pro-rated reduction, then the trigger will be tripped and the adaptive management pathway invoked.
Biological Relevance	In the event the trigger is tripped, CAMP1 data and other available scientific data will be used by Plum Creek and the Services to evaluate the biological relevance of non-attainment. The intent of this effort is to discern whether the sediment reductions realized by the NFHCP, while not meeting the threshold established by the trigger, will ultimately lead to an instream condition that precludes the recovery of functional habitat and viable fish populations for the permit species. Sediment core data (collected in the dominant geoclimatic regions) and other scientific data will be used to determine if sediment delivery reduction efforts are sufficient to result in a net reduction of instream fine sediments sufficient to allow for recovery of permit species. If so the expected benefit to permit species will be assessed.

TABLE AM-1-6
Use of CAMP1 Results in Adaptive Management

Adaptive Management Process Step	Use of CAMP1 Results in the Adaptive Management Pathway
Document and Determine Source of Change (Causal Linkage)	• Analyze study data to isolate the most direct cause of non-attainment (i.e., is it NFHCP ineffectiveness, large floods, etc.?). RSDAs may also reveal that watersheds with certain characteristics (such as highly erodible granitic soils) may be contributing to non-attainment. • Determine which NFHCP commitments relate to the causal factors identified above (such as new roads, old roads, etc.) • Determine why existing NFHCP commitments are not working (such as poor practices, unplanned use, changed circumstances, etc.)
Management Response	• Revise and/or add enhanced BMPs to do a better job of achieving intended results (such as refined placement of road drainage features, increased use of sediment traps, increased use of road surfacing, or road relocation/abandonment). • Revisions or additions will be directly related to causal factors identified (such as remedial response to flood damage or unauthorized use).

TABLE AM-1-7
Use of CAMP2 Results in Adaptive Management

<table>
<tr><th>Adaptive Management Process Step</th><th>Use of CAMP2 Results in the Adaptive Management Pathway</th></tr>
<tr><td>Triggers</td><td>Trigger B (SHO3)—Is there a net increase in canopy cover in riparian stands?
Trigger B will be considered tripped there is significantly less (alpha = 0.1) than a 2% per decade increase in canopy cover measured against the starting point in year 1.

Based upon riparian stand measurements taken for Trigger E, the average canopy cover for the Project Area will be calculated using the FVS model. Because modeled increases in canopy cover were initially estimated to be relatively modest, a change of canopy cover is not expected to be measurable before year 10.

Trigger D (SHO8) —Did the NFHCP forecasts accurately show impacts to woody debris recruitment associated with riparian harvest?
Because of time lags associated with measuring effectiveness of producing LWD, validation of woody debris recruitment modeling assumptions will be key to evaluating success in the first decade. The trigger is observed if forecasts using validated assumptions show that initial forecasts overestimated woody debris recruitment by 20% or more. This trigger will apply throughout the permit period.

The use of model validation for monitoring effectiveness for at least the first decade is necessary because long time frames are required to actually measure woody debris recruitment effectiveness. Reliance on the model is expected to diminish after the first decade.

Trigger E (SHO12)—Is LWD recruitment potential increasing over the Project Area?
The trigger will be tripped if, by year 15, the relative density and average size of the largest 88 tpa in riparian stands has decreased or stayed the same

Riparian stand composition in the nine dominant riparian stand types (Plum Creek 1999a) will be re-measured every 5 years, beginning in year 10. The trigger will first be reported in year 15.</td></tr>
<tr><td>Biological Relevance</td><td>In the event any trigger is pulled, CAMP2 and other available scientific data will be used by Plum Creek and the Services to evaluate the biological relevance of non-attainment. The intent of this effort is to discern if the fish habitat diversity realized by the NFHCP, as indexed by LWD loads and pool frequencies, will ultimately lead to instream conditions that preclude the recovery of functional habitat and viable fish populations. To aid this determination, habitat utilization by native fish in the demonstration watersheds will be monitored in conjunction with habitat, channel, and riparian conditions.</td></tr>
<tr><td>Document and Determine Source of Change</td><td>• Analyze study data to isolate the most direct cause of non-attainment (NFHCP measure ineffectiveness, large floods, etc.). Specific situations may also be identified where attainment is more difficult or impossible.
• Isolate the situations where management practices fail to meet objectives. Determine which NFHCP commitments relate to the causal factors identified above.
• Identify why existing NFHCP commitments are not working (such as not enough leave trees, leave trees too small, changed circumstances, etc.)</td></tr>
<tr><td>Management Response</td><td>If outcomes are determined to be biologically relevant, and the causal agents can be attributed to HCP inadequacies, then the following corrective steps will be implemented:

1. Use study data to describe specific stream reaches that require improved riparian measures.
2. Use study data to describe as specifically as possible causal factors identified as they relate to management actions.
3. Revise or create enhanced riparian prescriptions to address shortfalls.
  • Revisions or additions will be directly related to causal factors identified.
  • Revisions or additions should be applied to stream reaches demonstrated to be at risk.
4. In the event that commitments outperform expectations, describe management changes that would allow resources to be reallocated to other parts of the HCP that may be under-performing.</td></tr>
</table>

TABLE AM-1-8
Use of CAMP3 Results in Adaptive Management

Adaptive Management Process Step	Use of CAMP3 Results in the Adaptive Management Pathway
Trigger	**Trigger A (SHO1) Are impacts to stream temperature from riparian harvest minimized?** The trigger is a statistically significant (alpha=0.1) increase of 1.0 ^{o}C in maximum weekly average temperature based on a pooling of all measured sites . Note: Trigger B (SHO3) will also be used to measure performance for net impact to stream temperatures over the entire project area using canopy closure as a surrogate for the provision of temperature protection (See CAMP2).
Biological Relevance	In the event that the trigger is pulled for a particular stream gradient/width class, CAMP3 and other available scientific data will be used by Plum Creek and the Services to evaluate the biological relevance of non-attainment for permit species in the Project Area. At a minimum, the factors that must be evaluated to determine biological relevance are as follows: 1) The magnitude of the observed stream temperature change 2) The temperature range in which the change is observed 3) Fish species affected and what is known about their physiological requirements 4) The extent of the downstream persistence of the temperature change 5) Research data from other sources (e.g., laboratory growth research) 6) Fish habitat utilization in response to the observed temperature change, derived from measured habit use of control vs. treatment reaches
Document/Determine Source of Change	• *Analyze* study data to isolate the most direct cause of non-attainment (e.g., differential vulnerability of streams by width/gradient class, level of canopy cover reduction, change in microclimate, riparian habitat type) • *Isolate* the situations where NFHCP management practices fail to meet objectives. Determine which NFHCP commitments relate to the causal factors identified above (i.e., use pre- and post-harvest vegetation inventory data to identify which NFHCP treatments resulted in the measured change) • *Identify* why existing NFHCP commitments are not working (such as not enough canopy cover retention, not accounting for other stream heating/cooling processes, etc.).
Management Response	If Biological Relevance is positive and trigger can be attributed to NFHCP inadequacy, implement the following steps: 1) Utilize study data to describe specific stream reaches that require improved riparian measures. 2) Utilize study data to describe as specifically as possible the causal factors identified as they relate to management actions. 3) Revise or create enhanced riparian prescriptions to address shortfalls in meeting Habitat Objective #1: – Revisions or additions will be directly related to causal factors identified; – Revisions or additions should be applied to stream reaches demonstrated to be at risk. 4) In the event that over-performance is demonstrated, describe management changes that would allow resources to be reallocated to other parts of the plan that are under-performing.

So How Exactly Will Research Lead to Adapted Management?

In the first year of the NFHCP, Plum Creek will use the conceptual designs stated in this appendix as pilot projects that initiate the CAMPs and provide the additional detail needed to bring study designs to completion. By the end of year 1, Plum Creek, the Services, and outside scientists will collaboratively finalize the study plans for each of the Core Adaptive Management

Projects. At 5-year intervals during the NFHCP, major reviews will be conducted. It is at these pentennial reviews that effectiveness monitoring and other outside data will be evaluated. By March 31 of the Year 6 (and every 5 years thereafter), data from CAMP studies and external data will be used to determine if there is a statistically significant difference in performance expectations. There are five specific questions that must be evaluated to see if a "trigger" should be pulled (see Table NFHCP8-2).

When a trigger is pulled, the Adaptive Management Pathway is initiated (see Figure NFHCP8-1). The first step once a trigger is pulled is to evaluate if the departure from expectation is biologically relevant. If it is, and it is caused by an NFHCP commitment, then management must be adapted. The geographic extent of this modification would be based on the specific circumstance that was found to lead to the deviation.

An Example

A Trigger is Tripped. During the first 5 years of the NFHCP, Plum Creek collects data to support the trigger calculation for trigger C. Information is collected under CAMP 1 and at the end of year 5, research question #5 is used to calculate the trigger value. In this example, the calculated sediment reduction project wide is determined to be 7 percent. Since 7 percent is less than the prorated 5-year milestone of 10 percent, the trigger is considered tripped, thereby initiating the adaptive management pathway.

Determining Biological Relevance. The next step is to determine biological relevance. In CAMP 1, instream sediment levels are measured to give closer evidence of biological relevance (research question 3). As a part of the collaborative biological relevance determination, Plum Creek identifies that one of the three dominant geoclimatic regions seems to show greater evidence of sensitivity to instream sediment when comparing experimental and control watersheds. Additionally, Service biologists provide some recent literature that indicates that the measured instream sediment levels of two of the regions are at a level of concern and point to the Plum Creek data that indicates an increasing trend the last 5 years. A determination is made that tripping of trigger C is accompanied by a determination of biological relevance.

Evaluating the Causal Linkage. Since biological relevance was determined, a collaborative effort is undertaken to identify the causal linkages. Results from research question #4 indicate that sediment travel distances below roads are much greater when road surfaces and fills are lacustrine or mica schist. Furthermore, observations indicate that there is measurable rilling of dip outfalls in those soil types and the road fill erosion is thought to contribute to greater sediment travel distances. Also, external auditors report an "opportunity for improvement" based upon implementation audit observations in the Lochsa. They report: "while the second drainage feature from stream crossings meets the enhanced BMP criterion of 400 feet in most cases on upgraded roads, intervals seem to be pushing the maximum allowed. Also, rilling is observed in the closest drain dip to the stream." The audit shows that the NFHCP is being properly implemented, but identifies an "opportunity for improvement."

Developing a Mandatory Collaborative Management Response. Since the trigger was tripped, a biological relevance determination was made, and causal linkages were identified that link the departure to covered activities of the NFHCP, Plum Creek and the Services are required to collaboratively develop a management response in conjunction with the causal linkages identified. In our example, the following responses are agreed upon and become a binding requirement under the NFHCP:

- A new enhanced BMP for new roads and road upgrades is added, applying to the whole Project Area. It requires armoring of dip outfalls where road fills are composed of lacustrine or mica schist soils.

- An action plan is developed for the Lochsa operating area that involves two goals:
  - Armoring of close-to-stream dips will be retroactively implemented in Papoose Creek and Shotgun Creek watersheds
  - For future road upgrades, the interval before the second drainage feature from stream crossings will be shortened and average no more than 300 feet.

This example shows a trigger that was tripped on a project scale level that resulted in a programmatic project wide response that applies to specific soil types, to a planning area basin scale and to a third order watershed scale.